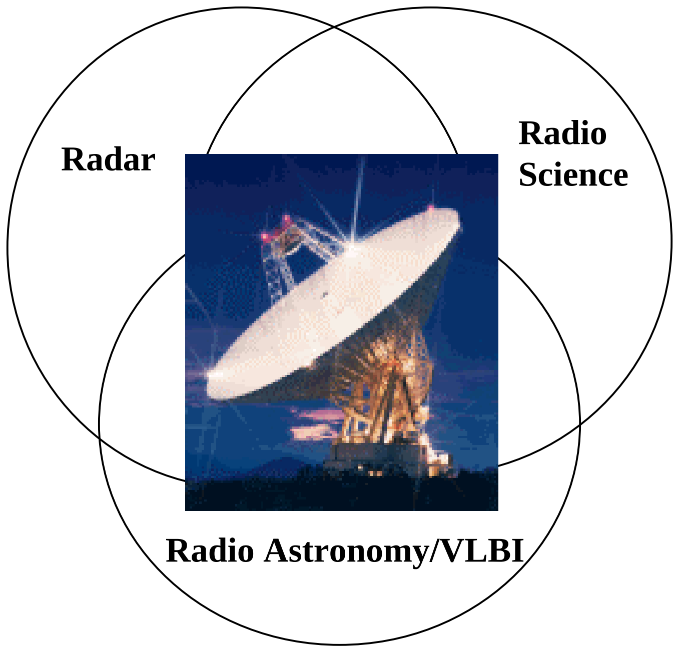
DSN Science Users' Guide

For Guest Investigators proposing to use NASA's Deep Space Network (DSN) as a science instrument



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Deep Space Network Science Office
Interplanetary Network Directorate
Jet Propulsion Laboratory
Pasadena CA 91109-8099

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http://dsnscience.jpl.nasa.gov/

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i. Letter to Investigators

National Aeronautics and Space Administration Washington DC

01 October 2002

Dear Colleague,

The Deep Space Network (DSN), operated by NASA for spacecraft telecommunications and navigation, is also used as an instrument for scientific research. The high power transmitters and sensitive receiving systems on the large aperture DSN antennas are effective instruments for scientific investigations in radio astronomy, solar system radar and radio science of the interplanetary medium using spacecraft as fiducial beacons. The global distribution of the DSN complexes make the three 70-m antennas particularly valuable components for international experiments using Very Long Baseline Interferometery (VLBI).

NASA's Office of Space Science and JPL's DSN Science Office are working to increase the accessibility to the wider community of the DSN radar and radio astronomy programs for scientific research which will contribute to technological enhancements of the DSN and NASA's science objectives. The information on this website is provided to assist scientists who would like to take advantage of the ground based science capabilities of the NASA DSN for research in Radio Astronomy, VLBI, Planetary Radar, and in Radio Science. The experiment proposal and selection processes are described and the limitations of the scheduling process are explained. Ground-based research programs are scheduled on a best effort basis by taking advantage of gaps in the high priority spacecraft schedules.

Observing time in the DSN is provided as a support service to the astronomical and radiometric sciences communities by the National Aeronautics and Space Administration on a time-available basis. Investigators are welcome to submit observing proposals in the four research disciplines, subject to the important consideration that one or more attributes unique to the DSN is required. Proposers should realize that the DSN is NOT a national observatory and are therefore encouraged to find an observing partner at JPL with experience using DSN facilities, instrument, and procedures.

NASA is being assisted by JPL in the administrative and logistical work needed to support this observing program. In addition to myself at NASA Headquarters, you may contact Michael Klein, Manager of the DSN Science Office at JPL, at (818) 354-7132 or e-mail mailto:dsnscience@jpl.nasa.govfor additional information.

We are looking forward to working with you to use the DSN as a science instrument in order to achieve the goals of the four science enterprises within the Office of Space Science.

Sincerely,

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1 Introduction

1.1 Purpose

This document is intended to guide potential science users of NASA's Deep Space Network (DSN). It is designed to: (1) allow potential investigators to assess the applicability of the DSN to their planned observations; (2) introduce the services and support functions that are available to scientists; (3) describe the process for proposing and gaining access to DSN Science services; and, (4) direct the reader to sources of more detailed information.

1.2 Scope

This Users' Guide covers the DSN's capabilities for direct scientific observations. Included are capabilities provided in the form of standard data services with well defined inputs and outputs and other services such as scientific collaboration, engineering support, and the use of R&D equipment. The use of the DSN for spacecraft tracking is not covered here except as it relates to Radio Science experiments.

1.3 Acronyms

The following is a glossary of acronyms used in this document.

AMMOS	Advanced Multi-Mission Operations System
DAS	data acquisition system
DSMS	Deep Space Mission Systems
DSN	Deep Space Network
IPN-ISD	InterPlanetary Network - Information Systems Directorate
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
R&D	research and development
RF	radio frequency
RTOP	Research & Technology Operating Plan
TMS	Telecommunications and Mission Services
VLBA	Very Long Baseline Array
VLBI	very long baseline interferometry

1.4 The Deep Space Network (DSN)

The DSN is an international network of antennas that supports interplanetary spacecraft missions and radio and radar astronomy. The network also supports selected Earth-orbiting missions.

The DSN comprises three deep-space communications facilities approximately 120 degrees apart around the world: at Goldstone, in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. This strategic placement permits continuous observation of spacecraft as the Earth rotates, and helps to make the DSN the largest and most sensitive scientific telecommunications system in the world.

NASA's scientific investigation of the Solar System is being accomplished mainly through the use of unmanned automated spacecraft. The DSN provides the vital two-way communications link that guides and controls these planetary explorers, and brings back the images and new scientific information they collect. All DSN antennas are steerable, high-gain, parabolic reflector antennas.

The antennas and data delivery systems make it possible to:

- Acquire telemetry data from spacecraft.
- Transmit commands to spacecraft.
- Track spacecraft position and velocity.
- Perform very-long-baseline interferometry observations.
- Measure variations in radio waves for radio science experiments.
- Gather science data.
- Monitor and control the performance of the network.

The network is a facility of NASA, and is managed and operated for NASA by the Jet Propulsion Laboratory. The Deep Space Mission System Program manages the program within JPL

1.4.1 The DSN as a Scientific Instrument

In addition to its function as a network of tracking stations for deep space missions, the DSN is used as an instrument for direct astronomical observations. These observations push the current capabilities of the DSN and often stimulate technology innovations that improve the performance of the network. Science observations are described by three categories:

Radio Astronomy/VLBI
The antennas of the DSN are used to receive and record RF radiation from natural sources (e.g., Quasars, stars, supernova). Spectral line observations as well as continuum measurements are supported. Observations are used to infer chemical, physical, and astrometric characteristics of the emitter.

Planetary Radar (Goldstone Solar System Radar)
The DSN transmits an RF signal towards a target and receives the reflection. Observations are used to infer the physical properties (e.g., surface characteristics, trajectory, rotation) of the reflecting object (e.g., planets, asteroids, rings).

Radio Science
The DSN receives and measures the signals from a spacecraft. Observations are used to study the influences on the motion of the spacecraft (gravity fields, gravitational radiation) or the transmission media (planetary atmospheres, rings, solar corona).

1.4.2 The DSN in the context of other astronomical observatories

The requirements of radio frequency spacecraft tracking and Radio Astronomy largely overlap. Both require high gain, low system noise, and frequency/phase stable systems. In regard to these parameters, described in more detail in Sections 2, 3, 4, and 5, the DSN is a world class facility and for many scientific observations, DSN antennas network with the world's premiere RF astronomical observatories (e.g., very long baseline interferometry (VLBI) observations with the National Radio Astronomy Observatories and the European VLBI Network; bi- and multi-static radar observations with Arecibo, Greenbank, and antennas in Germany, Russia and Japan).

The DSN differs from typical radio frequency observatories in that:

- Observing time for the DSN is provided as a support service to the astronomical and radiometric sciences community by the National Aeronautics and Space Administration on a time-available basis. Proposers should realize that the DSN is NOT a national observatory and are therefore encouraged to find an observing partner at JPL with experience using DSN facilities and instruments.

- Proposals to use the DSN for science should include a statement explaining why the DSN is required (or at least uniquely suited) to achieve the science objectives.

1.4.3 Partner Organizations: DSN Science Office and DSMS Program

As mentioned above, DSN Science capabilities are made available to users through a suite of services. These services are provided by the Deep Space Mission System (DSMS) Program and the DSN Science Office. The DSMS Program is responsible for the DSN and the Advanced Multi-Mission Operations System which support NASA's deep space missions. DSMS also provides science data services using mature DSN capabilities. These "standard" services have well defined operations input and output interfaces described in DSMS Service Requirements documents (see bibliography).

The DSN Science Office assists DSMS with the definition and development of standard services that have the widest possible application and then augments these standard services with other services customized for the individual users needs. Examples of these customized services are:

- The user and the DSN Science Office collaborate in the development of an experiment plan. The DSN Science Office executes the plan and provides the user raw or processed data.
- The user and DSN Science personnel collaborate in experiment operations.
- The user operates DSN Science capabilities using special science user interfaces, perhaps with engineering support from the DSN Science Office.
- The user provides and operates equipment to augment the DSN science capabilities

2 Radar Astronomy Capabilities

See sample of the radar material for the WEB page

http://wireless.jpl.nasa.gov/radar/

"Radar Operations Using DSS-14 and DSS-13"

prepared by Marty Slade et al (February 2002)

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3 Radio Astronomy Capabilities

The table which follows is taken from the Radio Astronomy website
http://dsnra.jpl.nasa.gov/

DSN Radio Astronomy Capabilities Overview

Last updated by Tom Kuiper on 2002 July 25

In the table, *Italics* indicate equipment under DSN configuration control. Such equipment cannot be modified or reconfigured for radio astronomy experiments, but may be used as is. White table cells indicate a future capability.

DSN Complex / Location	Station ID / Coordinates	Diameter (m) / Type[1] / Az. Range[2]	Frequencies (GHz)	Aper. Eff.	System Temp. (K)	Polarizations	Observations Types Supported	Spectrometers: Name	Type	Num. of Channels	Bandwidth (MHz) Min.	Bandwidth (MHz) Min.	VLBI[3] Recorders
Canberra DSCC / Tidbinbilla ACT Australia	**DSS-34**	34	*2.2 - 2.3*	0.7	*18*	*LCP or RCP*	VLBI	DAVOS	FFT	16384	20	20	*Mk IV*
	148 59' E -35 24'	BWG	4.7 - 5	0.7	24	LCP and RCP							S2
			8.4 - 8.5	0.7	*24*	*LCP or RCP*							
		-315/+180	*31.86 -- 32.08*	0.5	*24*	*LCP*		Parkes	AC	8192	0.0625	16	
	DSS-43	70	*1.610 - 1.705*	0.5	*25*	*LCP*	Radiometry Spectroscopy VLBI						
	148 59' E -35 24'	ME	*2.2 - 2.3*	0.7	*186/I>*	*LCP and RCP*				4096	32	64	
			8.4 - 8.5	0.7	*24*	*LCP and RCP*							
		-225/+360	18 - 26.5	0.5	40	LCP and RCP		sao4k[4]	AC	4096	0.125?	400	
	DSS-45	34	*2.2 - 2.3*	0.7	*18*	*LCP and RCP*	VLBI						
	148 59' E -35 24'	HEF	*8.4 - 8.5*	0.7	*24*	*LCP and RCP*							
		-315/+180											
Goldstone DSCC / Ft. Irwin CA USA	**DSS-12**[5]	34	2.245 - 2.345		20	LCP or RCP	Radiometry						
		equatorial											
	DSS-13[6]	34	2.245 - 2.345	0.7	20	LCP or RCP	Radiometry Spectroscopy VLBI	WBSA	FFT	8192	0.15625	40	*Mk IV*
	243 12' E 35 15'	BWG	8.4 - 8.6	0.7	20	LCP and RCP							Mk IV
			10 - 12.5	0.7	20	crossed linears							
		-90/+360	18 - 26.5	0.6	50	LCP and RCP		CSP	FFT	8192	0.15625	80	
			27 - 37	0.5	65	LCP and RCP							
			37 -- 50	0.5[7]	100	LCP and RCP							
			77 - 100	0.15[7]	150	linear		spb500	AC	1024	0.125?	500	
	DSS-14	70	*1.610 - 1.705*	0.5	*25*	*LCP*	Radiometry Spectroscopy VLBI						
	243 08' E 35 26'	ME	*2.2 - 2.3*	0.7	*18*	*LCP and RCP*							
			7.9 - 8.7	0.7	24	LCP and RCP		jpl1k	AC	1024	0.125?	400	
		-220/+310	18 - 26.5	0.5	60	LCP and RCP							
	DSS-15	34	*2.2 - 2.3*	0.7	*18*	*LCP and RCP*	VLBI						
	243 07' E 35 25'	HEF	*8.4 - 8.5*	0.7	*24*	*LCP and RCP*							
		-315/+180											
	DSS-24 DSS-25 DSS-26	34	*2.2 - 2.3*	0.7	*18*	*LCP and RCP*	VLBI						
		BWG	*8.4 - 8.5*	0.7	*24*	*LCP and RCP*							
	243 08' E 35 20'	-90/+360	*31.86 - 32.08*	0.5	*24*	*LCP*							

Madrid DSCC	**DSS-54**	34	*2.2 - 2.3*	0.7	*18*	*LCP or RCP*	VLBI	Spectra-Data	FFT	512	1	10	*Mk IV*
	355 45' E 40 26'	BWG	*8.4 - 8.5*	0.7	*24*	*LCP or RCP*							S2
		-90/+360	*31.86 -- 32.08*	0.5	*24*	*LCP*							
	DSS-63	70	*1.610 - 1.705*	0.5	*25*	*LCP*	Radiometry Spectroscopy VLBI						
Robledo Madrid Spain	355 45' E 40 26'	ME	*2.2 - 2.3*	0.7	*18*	*LCP and RCP*							
			8.4 - 8.5	0.7	*24*	*LCP and RCP*		sao4k[7]	AC	4096	0.125?	400	
		-220/+310	18 - 26.5	0.5	40	LCP and RCP							
	DSS-65	34	*2.2 - 2.3*	0.7	*18*	*LCP and RCP*	VLBI						
	355 45' E 40 26'	HEF	*8.4 - 8.5*	0.7	*24*	*LCP and RCP*							
		-90/+360											

1) **BWG**: Beam Waveguide, an azimuth/elevation mounted with a radio Coudé focus.
HE: High Efficiency: azimuth/elevation mounted antenna with coaxial S/X feeds at the Cassegrain focus.
HSB: High Speed Beam Waveguide, designed for tracking near-Earth objects.
ME: Master Equatorial, an azimuth/elevation mounted antenna slaved to an equatorially mounted direction indicator.

2) The elevation range of all azimuth/elevation mounted antennas is 6 to 88 though shadowing by mountains may further constrain the minimum elevation.

3) All stations have a hydrogen maser frequency standard and are time-synchronized to the GPS.

4) sao4k belongs to the Smithsonian Astrophysical Observatory. It is available when onsite (generally during the local winter) by special arrangement with Dr. Lincoln Greenhill.

5) Telescope is dedicated to K-12 education programs. Requests for use should be directed to the Lewis Center for Educational Research, Apple Valley, CA (gavrt.org)

6) DSS-13 is the DSN R&D facility. It is not used for routine spacecraft tracking. None of the equipment is under DSN configuration control.

7) Above 40 GHz, only the inner 26-m of the antenna are illuminated because of the perforations in the outer panels.

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4 VLBI Capabilities

One-page SUMMARY with reference link to appropriate WEB page
http://vlbi.jpl.nasa.gov

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5 Radio Science Capabilities

One-page SUMMARY with reference link to appropriate WEB page
http://radioscience.jpl.nasa.gov/

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6 How to Propose as a Guest Investigator

6.1 Science Proposals

There are three classes of DSN Science users.

1. **Institutional Investigators** such as an existing mission (like the Space Interferometry Mission – SIM), Radio Science investigators associated with DSN supported flight projects or an outside organization (such as the European VLBI Network);
2. **Programmatic Investigators** such as those supported by peer-reviewed NASA research and technology plans (RTOPs) which require the use of DSN facilities, and those investigators operating under Host Country or similar agreements;
3. **Guest Investigators** who submit proposals directly to the DSN Science Office for use of the DSN Science services.

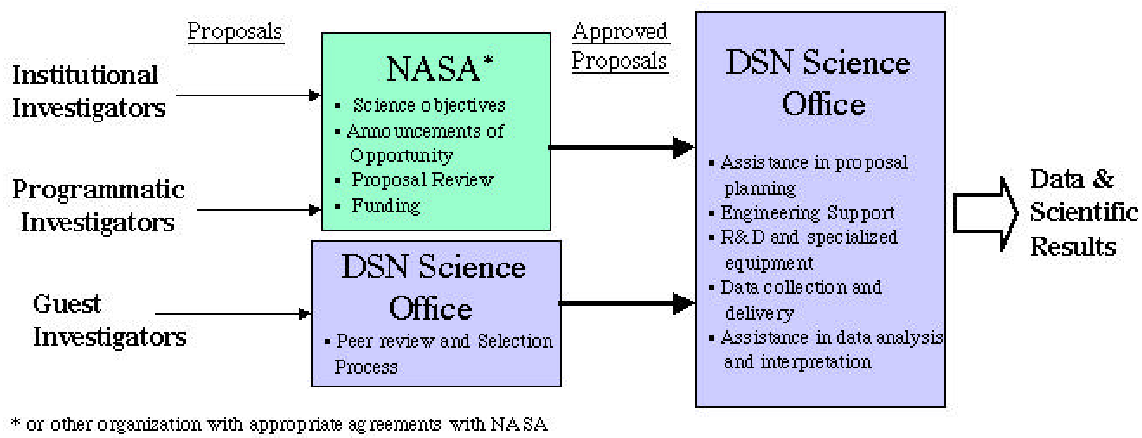

Figure 1: DSN Science User Community

All science users receive permission to use the DSN on the basis of their experiment proposals. Institutional and programmatic investigators submit proposals to other, appropriate organizations. Guest investigators submit an experiment proposal to the DSN Science Office (see Figure 1). Experiment proposals to the DSN Science Office should include:

- science objectives
- observation strategy
- proposed equipment configuration

· 6.1.1 Science Proposal Process.

The process for Guest investigators to propose and conduct experiments with the DSN is discussed in this section. The diagram of the process is shown in Figure 2.

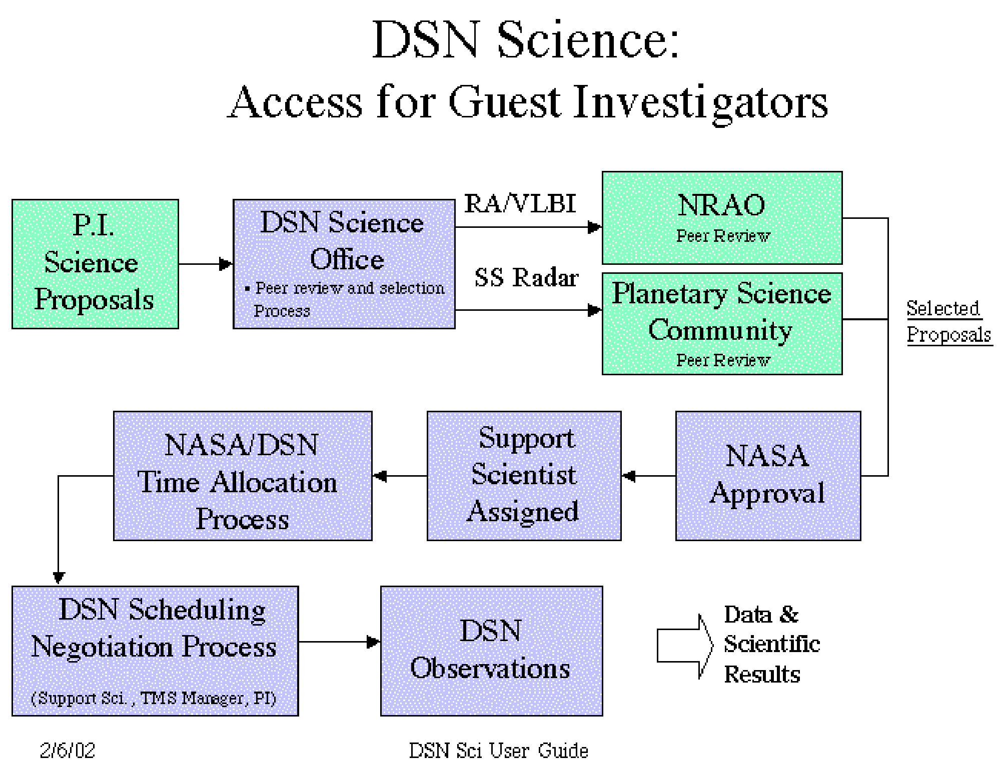

Figure 2: DSN Science: Access for Guest Investigators

1. Potential users browse the DSN Science Users' Guide or other sources of information to determine their level of interest in DSN Science capabilities. The Guide gives names, phone numbers, and e-mail addresses of the DSN Science Leaders and potential users may obtain further information and assistance from them during proposal preparation regarding DSN capabilities, user interface, instrument budgets, etc.

2. Guest investigator proposals are submitted to the DSN Science Office for initial evaluation. If the proposal passes this level of review, it is sent to the appropriate area Science Leader for assessment of feasibility given current or planned capabilities. If the proposal meets these criteria, there is a peer review appropriate to the required DSN. The disposition of the proposal (approved, rejected, or approved with conditions) is transmitted to the proposer by the DSN Science Office. Typically there is a minimum of six months needed from proposal submission to scheduling observing time.

3. On the basis of the review, the proposal will be judged "accepted", "accepted with conditions", or "rejected". In the case of proposals accepted with conditions, the conditions for acceptance accepted will be clearly defined. In the case of rejected proposals, the proposal response will state the reasons the proposal was not accepted. Proposers should allow six weeks after the DSN Science Office's receipt of the proposal for the proposal to be evaluated.

There are special cases where the six-week evaluation period will be waived. In these cases, such as an important target of opportunity requiring quick response, the DSN Science Office management may expedite the approval process and attempt to re-allocate resources. Also, proposers may request pre-review of proposals for targets of opportunity (e.g., radar observations of asteroids just discovered).

Once a proposal has been accepted, the extent and nature of DSN Science services are negotiated with the appropriate Science Leader. DSN Science roles and responsibilities are documented in an experiment plan, which is reviewed and approved by the appropriate Science Leader or their representative. A Support Scientist is appointed to assist the PI Scientist with the implementation and execution of the observing plan.

6.1.2 Proposal Acceptance Criteria

Proposals are evaluated on the basis of:

- scientific merit
- the amount and nature of required DSN resources
- the value of the observations to the overall evolution of the DSN both as a scientific instrument and as a network of spacecraft tracking stations
- the value of the observations in the context of other scientific observations
- the relevance of the observations to NASA's science objectives

6.1.3 DSN Scheduling Constraints

Observing time allocation for DSN Science experiments are constrained by the loading of the DSN in support of the large number of the ongoing flight projects. DSN Science projects are also subject to last minute rescheduling (or cancellation) if a flight project emergency is declared. Despite these constraints, DSN Support Scientists are welcomed participants in the DSN Resource Allocation Process where they have established a good record for negotiating sufficient time to achieve the science objectives of the experiments they represent.